On (not) assembling a market for sustainable energy

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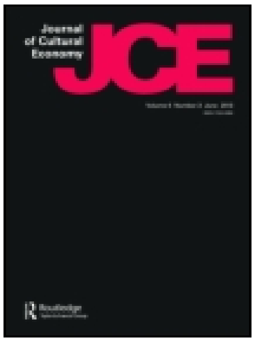

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On (not) assembling a market for sustainable energy: heat network infrastructure and British cities

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ABSTRACT
Energy policies increasingly rely on market instruments to meet societal objectives for climate change mitigation. We explore the application of such instruments in low carbon heat markets. Using a conceptual framework derived from actor network theory and economic sociology, we examine the role of technical-economic models as market devices in two heat network proposals in British cities. Government intermediaries relied on the models to enact the mutual financial and carbon benefits of an area-wide heat market, and to enrol multiple public sector organisations in innovation. In practice, the models produced the opposite response: parties synthesised the modelled cost–benefit calculations into the existing public services market *agencement* and translated the model numbers ino opportunities to secure competitive advantage for their own organisation. These activities undermined the projected cost and carbon saving logic of the collective actor solution. The findings demonstrate the potent economic agency of market-emulating public finance and competitive procurement instruments in governing such organisational decisions, and indicate the limited traction of a low carbon calculus, which lacked significant political or senior management sponsorship. Questions are posed about the formatting of economic agency suited to securing the common goods of a sustainable society.

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Introduction

> Rather than pick a winning technology, the Government will create markets that enable competing low carbon technologies to win the largest market share as the pace of change accelerates in the 2020s UK Carbon Plan, 2011, p12.

Advanced capitalist societies depend fundamentally on coal, oil and gas, but this dependence is producing increasingly severe societal risks from climate change. Although government policies encode commitments to new sustainable energy, implementing such radical change is without precedent, and means of governance are uncertain. The UK Carbon Plan 2011 positions markets as key instruments of cost effective innovation. Markets have well-established advantages in economic coordination, and creative responses to new information, but there are significant questions about their adaptability as policy instruments to mitigate climate change. Most famously, Stern's (2007) report to the UK government concluded that climate change represents the most significant market failure in history, reiterating a basic tenet of economics that markets are particularly unsuited to production of public goods. Political commitment, grounded in normative economic theory of efficient markets,

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has nevertheless focused on their expected advantages for low carbon innovation. Normative theory asserts that the utility-maximising self-interest of those 'with the resources to act as market agents' (Mitchell 2011, p. 196) motivates discovery of the least cost means to a clean energy system. Government's role becomes that of 'supporting the market to discover solutions', including shaping the market 'where necessary to overcome barriers' (UK Government DECC 2013, p. 7), and keeping options open by providing 'information for market players … to enable effective decision-making' (p. 79) about cost-optimal solutions.

Our paper examines the application of this policy model to the attempted creation of markets for low carbon heat networks, which use underground hot water pipes to supply heating, and hot water, to clusters of buildings. Our conceptual framework is derived from a material sociology of markets, where materiality comprises the *physical* artefacts of energy technology, the *technicalities* of economic, contractual and regulatory instruments, and the *affective, cognitive and social qualities* of human beings (MacKenzie 2009). The framework seeks to avoid a normative stance on markets, focusing instead on empirical analysis of their heterogeneous socio-technical constituents and processes of qualification, production and circulation of goods (Caliskan & Callon 2009, 2010). The conceptual framework opens up questions about the scope for reflexivity in designing markets for different purposes, including public goods such as a stable climate. We used this approach to study two experiments in assembling a heat market, focusing on the interaction of public sector organisations, envisaged in policy as 'market players', with technical-economic models intended by government intermediaries to work as devices to establish new facts about the energy, cost and carbon efficiencies of collaboration in a heat network infrastructure.

In current UK climate change policy, a number of heat technologies are considered likely to contribute to 2050 zero emissions targets for buildings,[1] including electric heat pumps, combined heat and power (CHP) generators, thermal treatment of waste and biomass or biogas boilers. Heat networks can use these and other technologies to share available heat sources, especially those more feasible at larger scale and usually wasted, among clusters of buildings, and are intended to enable more efficient overall use of resources (Lund et al. 2014). The economies of scale associated with larger networks have cost, carbon saving and welfare benefits, because they combine higher density and diversity of heat demand. This decreases average cost per user and allows higher value to be extracted from heat sources and infrastructure. Organisations such as hospitals, with high and stable patterns of heat use, are hence critical components of an actor network capable of 'anchoring' system economics (King & Shaw 2010). UK policy models use technical-economic data-sets, similar to those replicated at locality scale in our case studies, to construct scenarios for future 'cost-optimal' supply of low carbon heat. This modelling is used in policy statements to suggest that heat networks could supply somewhere between 20% and 43% of heat from 2030 out to 2050 (UK Government DECC 2013, p. 45).

As in other network infrastructures, developing a heat network is a collective actor problem. Collaboration and long-term interdependence between heat suppliers, distributors, retailers and users are necessary to securing the envisaged benefits from carbon, energy and cost saving. These benefits are not however restricted to direct participants in development, and each direct participant may calculate the costs to them as outweighing their share of expected benefits. The selfish rational actor solution is to free ride on the willingness of other parties to take responsibility. If all parties adopt the rationally self-interested position, however, the common benefits are lost to all. Historically, the collective actor problem in network infrastructure has been resolved through combinations of public planning, regulation and ownership. The British fossil fuel gas grid, for example, was built under public ownership as part of macro-economic policy. The gas and electricity grids were privatised in the 1990s, and energy policy in the UK now relies on configuring markets attractive to commercial investment. Unlike the gas grid, however, new heat infrastructure lacks regulated guarantees on investment and is hence positioned as economically marginal in current markets. The challenge for demonstration projects is to assemble a district heating business to meet a 'commercially viable threshold' (UK DECC 2013, p. 58) outside this regulated sector, in turn contributing to discovery of 'the economically optimal extent of heat networks' (UK Government DECC Official). Solving the collective actor problem for heat networks is hence largely reliant on market experiments (Callon 2009) to qualify the infrastructure as economically competitive.

Using a material sociology of markets to analyse low carbon heat proposals

The contemporary materialist analysis of markets has developed mainly from European sociology and anthropology of economics (see e.g. Callon 1998), actor network theory (Callon & Latour 1981) and sociology of scientific knowledge (MacKenzie 2009). It is distinct from other economic sociology traditions in at least two respects. First, rather than treating sociological theory as an alternative explanatory model to economics, it examines the mutually constitutive relationships between economic sciences, markets and processes of economisation in modern societies. In other words, a market is analysed as 'an achievement rather than … a pre-existing reality that can simply be revealed and acted upon' (Caliskan & Callon 2009, p. 370). This perspective asserts that economic theories may have 'performative' effects through instruments which create the conditions for a theoretical proposition to become true. In other words, economics may equip humans and their organisations with means to conform more closely to the imagined *homo economicus* of normative theory. Second, and relatedly, its model of economic agency is conceived not as residing solely with human actors, but as distributed across heterogeneous socio-technical actor networks, or *agencements,* of human and non-human constituents, including economic instruments, regulatory institutions and physical infrastructures which mould calculative capacities, and configure agents capable of qualifying goods and assessing their value (Caliskan & Callon 2010). This avoids the foundational assumption of an economic agent with a fixed ontology or properties: capacities and characteristics are defined by the components of particular *agencements* (Hardie & MacKenzie 2007).

By focusing on the specificity and particularities of *market* relations the material sociology perspective aims to go further than a social constructivist analysis; hence it investigates the constitutive role of economics in creating knowledge about, and designing, markets. It also introduces questions about the workings of 'economics at large' (Callon 2007), including finance, accounting and marketing disciplines, in prioritising and diffusing concepts of market efficiencies, calculability and comparative profitability of investments, and in extending the metrics and techniques available for their appraisal. The making of a market resource and facts about its value are therefore objects of enquiry, rather than being treated as abstractions or as pre-given entities (Caliskan & Callon 2009). This does not mean ignoring human sociality, cognition and affect, which are the embodied components of a hybrid actor network, and which interact with the technical instruments of markets in shaping dynamics of trust and distrust, cultural scripts and decision-making processes (Beckert 2011; Fligstein & Dauter 2007). The performativity of option pricing theory in financial markets was for example demonstrated by MacKenzie and Millo (2003), but this was not an a-social impact of a technical pricing formula on a fluid actor network. Instead the performativity of the theory was a historically contingent and contested outcome, dependent on promotion through elites, as well as embedding in the moral communities of the markets, based on social evaluations of reputation, trustworthiness and respect.

The material sociology perspective is used here to contribute to ethnographic studies of market experiments, where markets are instruments of low carbon energy policy. Such ethnography is central to a research programme for empirical analysis of economisation processes in capitalist societies (Caliskan & Callon 2010). It directs attention to shifting formations of economic agents, struggles over valuations of goods, and the innovation potentials of markets in solving collective actor problems. Market experiments, shaped by 'economics at large', Callon (2008, 2009) suggests, are becoming more common, drawing in wider circles of technical and legal experts, businesses, civil society groups, scientists and governments. Such experimentation not only aims to open up new forms of market organisation, but also incorporates more explicitly the political dimensions of economisation. This seems especially evident in relation to climate change, where markets have been instrumental in creating the problems which market experiments are now expected to solve. In theory, however such controversies

> no longer appear as an obstacle to the functioning of markets, nor as a sign of the untruthfulness of calculations, but as crucial moments in building the collective involved in market innovation and in generating knowledge on the qualities of clean technologies. (Doganova & Karnoe 2015, pp. 29–30)

Framing, drawing boundaries around, and stabilising the value of, relevant qualities of a low carbon technology are fundamental to making market experiments work. But such qualities and their valuations are contested, as parties challenge their definition and bring excluded qualities back into the frame (Callon 1998). Market devices, defined as the 'material and discursive assemblages that intervene in the construction of markets' (Muniesa et al. 2007, p. 2), are usually critical to the dialectics of such framing and overflowing. They construct facts about the qualities of proposed products, and their exchange value, seeking to make such qualities visible, stable and tradable (Doganova & Eyquem-Renault 2009), as a means to enrolling parties in market innovations.

In our cases, we focus on the particular market device of the consulting engineers' report, which is advanced by government intermediaries and circulates among the prospective parties. The report constitutes a technical-economic business model for an envisaged heat market experiment. It consists of strategic selection and construction of data from complex and uncertain fields of possibility; it simplifies and distills projected facts about value creation, translating these into a plausible, and consistent, narrative (Doganova & Eyquem-Renault 2009; Garud et al. 2014). In technology entrepreneurship, Doganova and Eyquem-Renault (2009) conclude that business models are not 'discovering' pre-existing opportunities, but constituting something as a comprehensible, credible market opportunity through recursive interactions with potential parties. The model aims to shape calculations of value, adapting to different responses, drawing in and building the actor network of a prospective venture. In our cases, the technical-economic models condense the interdependencies and complexities of energy market futures into a simplified narrative and data-set designed to qualify the physical infrastructure of heat networks as cost and carbon competitive against a gas heating comparator. We explore the encounters between the model and the prospective 'market players' and ask why assembly of heat market *agencements* proved precarious. In conclusion, we reflect briefly on the significance of the findings for use of markets as instruments to solve collective actor problems of energy and climate change.

Assembling a market for low carbon heat

Our case studies concern attempted assembly of a market for buying and selling heat (rather than gas from the established grid); this required investment in a new underground pipe network carrying heating and hot water from gas-fired CHP engines[2] to clusters of large public sector organisations. Since these are contemporary cases and their trajectory remains uncertain, the localities are identified only as East and West cities. Two different government agencies, each with responsibilities for low carbon business innovation, brokered interactions between hospital, university and city council officials, consulting engineers, lawyers and finance experts. Research access was negotiated with each party. Fieldwork entailed multiple methods: first, review of local authority and government energy strategies, district heating proposals, heat maps and technical-economic models; second, observation of project meetings and participation in cross-sector knowledge exchange workshops[3]; third, we conducted semi-structured interviews, combining a biographical and problem-oriented format, and lasting from one to two hours. In the paper, we rely particularly on 18 interviews with a total of 20 contributors; the larger project data-set of 114 interviews with 159 government, business and civil society contributors informs our understanding of policy, technical-economic models, contractual and regulatory structures and environmental finance. The key interviews used in the paper were audio-recorded, transcribed and analysed thematically.

Using markets to solve problems of innovation in low carbon heat: East and West City heat network proposals

In line with energy market policy, the proposals for heat networks sought to assemble financial value from anticipated public goods of clean energy. Building the physical infrastructure of the network however presented a collective actor problem of consent to long-term social, economic and technical interdependencies in exchange for public goods of clean energy. The resulting enterprise would be greater than the sum of its parts by sharing costs and benefits to secure the projected long-term sustainability value of heat networks.

In East City, officials from government agencies, university, health service and city council met in May 2013 to consider 'if there is a willingness amongst stakeholders to consider the feasibility of a project to develop a heat network' (Briefing Note) at a significant green field site. The site was defined as having 'strategic economic importance' for 'green growth' in the context of a city plan 'reliant upon the competitiveness and the attractiveness of East City as an investable place' (Chris, East City economic development officer). Site development had commenced a decade earlier with construction of a major teaching hospital and university research facilities. Their co-location, and commissioning of a further hospital, were integral to plans for mobilising private investment:

> We have an American partner who creates life science parks throughout the world, or did until the market downturn. (Jake, enterprise officer)

Development of the green field site was contentious, and strict planning conditions set a CO_2 emissions' reduction target 50% more ambitious than baseline standards. This was expected to be more attainable than in city centre retrofit. The key market device relied on by government intermediaries as an instrument of innovation was a technical-economic business model projecting mutual long-term energy, cost and carbon savings from an area-wide heat network.

A year earlier in West City, officials from the Carbon Trust,[4] two universities, the health service, a further education college, the city council and government met to discuss a similar technical-economic model, but this time for heat network retrofit for an existing West City Centre Cluster of buildings. The proposals stemmed from a West City Future initiative, led by the city council and one university, which again relied on mobilising private finance through a 'green growth' narrative. The initiative cited commercial partners including two major energy companies and a New York investment bank, and positioned heat network infrastructure as the technically and financially integrated backbone of sustainable urban regeneration.

In both cities, all public sector organisations stated willingness in principle to collaborate. In practice, National Health Service (NHS), university and college participants have since proceeded to model the economics of separate energy systems, including their own CHP and heat network schemes, and have in some instances commenced investment; these activities undermined the projected carbon and energy saving logic of the collective actor solution. We examine below how this came about.

The technical-economic model as market device: assembling narrative and numbers about value

Each of the technical-economic business models narrated a future market among heat buyers and sellers, structured by the physical artefacts of a new energy centre and heat network supplying clusters of buildings. Value was framed in relation to long-term contracts for sale and purchase of heat: buyers would secure a competitive price, while meeting carbon targets; an unspecified infrastructure investor/heat seller would correspondingly gain an 'attractive' financial return from secure revenues. In the model, the opportunities were configured around the parties' consent to act as the 'right' kinds of long-term customers: their continuing need for large-scale heat supply would anchor the economics of the network. The hospitals would be the most significant customers, followed by the universities and council or government buildings; nearby multi-storey commercial and housing blocks would provide secondary revenue streams for subsequent expansion.

The modelled viability of propositions hence centred on financialised measures of value, rather than a multi-dimensional construct of use value of the asset as a long-term public good. The modelled translation of proposed heat networks into a profitable income stream for a financial investor was achieved through a time discounted cash flow technique derived from finance theory (Chiapello 2015). In these cases, the technique compresses complex and probabilistic models of future energy prices, infrastructure cost and performance, heat production and supply and carbon emissions into a single data-set. This projects the financial value of investments in a single monetary indicator of net present value of future cash flows. A discount rate, representing the cost of capital, is applied to this calculation, and its level is critical to defining the relative profitability of different investments. Choice of discount rate is shaped by economic definitions of the time value of money: a higher value is placed on the present than on the future, and the greater the future uncertainty of cash flows the higher the discount rate, making the project less viable for investment (Chiapello 2015). A lower, or 'social', discount rate places greater value on long-term societal benefits. Cash flows for heat networks, which are unregulated assets in a regulated energy market, are usually assessed as uncertain, increasing the discount rate and resulting cost of capital. Hence, heat network proposers need to enrol heat buyers in long-term contracts, in order to secure future cash flows. East and West City technical-economic models used discount rates of 6% and 7.5%, respectively. These rates are intermediate between the UK Treasury social discount rate of 3.5% and commercial rates of 10% and above, and therefore positioned the public sector parties as consenting to long-term purchase of heat, and implied that at least part of the capital investment would also come from them, as a guarantee to private investors.

In the East City science park proposal, the financial returns and carbon savings in the first model depended on the planned second hospital, which would comprise around half of heat demand. The estimated reduction in greenhouse gas emissions was 30% per year relative to separate gas boilers, and financial returns to an investor were projected at 12%. As we explain below, the NHS resisted enrolment in such a heat market experiment, and a further iteration of the model, incorporating alternative configurations of buildings, network scale and heat sources, was commissioned. Loss of the hospital as a heat buyer meant that modelled carbon savings in this subsequent version were either negative or considerably reduced, ranging from −4% to 12%, and the corresponding calculus of return on capital investment varied from −0.7% to 12.3%. In West City, the consultants' 2012 technical-economic model had also revised an earlier version, and this second iteration estimated that, at 16,600 tonnes CO_2 per year, the network would achieve almost five times the carbon abatement shown in the initial model. This would require twice the capital (£14 m), but the payback period was assessed as eight years, rather than nine and a half, and the estimated 12.6% return on investment was double.

In both cities, the focus on financial value for an unspecified investor meant that the uncertainties behind the numbers, and who would invest in what, under what identity, became critical in processes of circulation and negotiation of the technical-economic models. The models' projections of mutual financial gain were contested and reinterpreted, as parties challenged the framing of relevant product qualities, and the stability of facts about them, and questioned the allocations and valuations of costs and benefits.

The encounter between heat market models and a public services market agencement

In one sense, the models were effective in assembling a calculus of financial value, but it was not the one sought by government intermediaries and projected by the models. As discussions progressed, it became evident that the technical-economic data was instead assimilated as component actor in an existing public services market *agencement* powerfully configured by competitive procurement and private finance instruments and 'best value' rules in public spending; these economising techniques framed the calculative capacities and characteristics of the parties.

At the East City site, for example, both existing and new hospitals were commissioned using UK Private Finance Initiative (PFI)/Private Public Partnership (PPP) instruments: capital for construction and servicing of the facilities comes from a private sector investment consortium; long-term debt is repaid from public sector revenue budgets. The PPP framework is itself premised on normative theory of market efficiency in construction and operation of public infrastructure, although this has become increasingly contentious. A UK Parliament Treasury Committee (2011) report concluded for example that, since the financial crisis, PPP projects have been significantly more expensive to fund than they would be under direct public borrowing, and that evidence of benefits sufficient to offset the significantly higher cost was lacking. The Treasury Committee (2011) report commented specifically on the inflexibility of the private finance instrument for NHS facilities, due to the 'financing structure and its costly and complex procurement procedure' (p. 5). Procurement of the new East City hospital under PPP rules was nevertheless proceeding in 2013, imposing strict calculative and temporal constraints on the assembly of a collective actor solution around a heat market. A particular area of contention in East City discussions between NHS team and government intermediary was the envisaged intractable legal problems in a relationship between a hospital private sector consortium, who would face financial penalties for failure of heating and hot water supply, and a separate heat supplier. The cognitive and affective pressures on managers responsible for procurement of the hospital, under the politicised PPP model, contributed to contentious negotiations. Ultimately, the procurement documents specified a requirement for a CHP system serving *only* the hospital estate, undermining the collaborative heat market proposal brokered by the government agency:

> It was very, very disappointing for us. (Margaret, Enterprise Officer)

The agency sought to salvage potential for future collaboration through NHS agreement to insert a requirement for future connection to a heat network in revised procurement documents. Ironically this weaker bid to enrol the NHS was undermined by a second government body, responsible for infrastructure commissioning, which argued that any variation in procurement terms risked financial penalties, and set undesirable future precedents: unsuccessful bidders could seek compensation for the work of amending their original bid.

The heat market model had also incorporated financial benefits for both the NHS and a heat network investor from sale of surplus heat from the existing hospital's CHP system to a shared network. This was in turn undermined by the existing 30-year PFI framework contract, which had commenced in 1998 and constituted any variation in contract terms as a cost-bearing risk:

> It just seems to be an absolute nightmare … it's twelve banks that are financing it, and for any decision to be taken, all 12 banks need to agree … So [investment consortium] have told us before, and told the NHS, that they do not wish to see any change in their risk profile and any change in their profit, because that will cause the banks major headaches, because … they're buying into an income stream … (Margaret, Enterprise Officer)

The PFI/PPP configuration of a public hospital as an 'income stream' again prioritised financial value for private investors over the public value of energy and carbon saving. The calculations of value by NHS participants interacting with the heat market model were powerfully configured by this public services market *agencement* of commercial contracting and private finance. This assemblage worked against more open-ended evaluation of innovation for an area-wide, collaborative solution to low carbon heating and hot water supplies at the greenfield site.

Heat market models and 'best value' rules in public finance: intersections of price, fairness and reputation

West City negotiations also assimilated the technical-economic model into the public services market *agencement*, illustrated here in relation to market framing of Best Value in public spending[5] and associated 'competitive advantage' discourse. The modelled allocations of costs and benefits in a heat market were a focus for struggles over fairness of the propositions, and hence over their viability. This was not about fairness in a simple sense of price comparison, but about fair price as configured by alternative formulae. In this case, an existing public sector energy procurement 'club' established the standard for best value price comparison and definition of relative fairness. In the procurement club, higher gas users received a cheaper tariff, giving the NHS the lowest unit cost for gas heating. The heat market model projected a *standard* tariff for all customers, and sought to demonstrate some additional value for each party, but allocated *zero* savings on supply price to the NHS. Furthermore, the modelled location for a shared energy centre was on the hospital site; the narrative noted that this implied demolition of a building and use of land with potentially high value to the NHS, but the associated costs were excluded from the calculus. Nevertheless, the highest financial gains in the model were allocated to the hospital, but these came from a discounted price for electricity (supplied from the new on site CHP engine) and the avoided carbon taxes from the then UK tax on large energy users.[6] The second highest financial gains, which were only 10% below those allocated to the hospital, accrued to one of the universities, which was expected to buy only one-third the amount of heat bought by the hospital. NHS officials assessed the modelled costs and benefits allocated to the hospital as unfair, arguing that their share of costs could be interpreted as subsidising benefits accruing to others.

For all of the parties, definitions of fair or best value were also framed by a media discourse about 'wasteful' public spending and the non-monetary value of a public reputation for thrift:

> [A freedom of information request could reveal] you were paying x before, now you're paying x+10; who thought that was a good idea? Then your name's all over the papers about squandering … (Robert, West City estates manager, university B)

> If the press gets hold of it, the press just tears these things to shreds and blows them out of proportion. (Graham, West City NHS estates manager)

The reverse counterfactual, that procurement club prices would *exceed* those of the shared heat network, was not a cause for concern. Within the club, although the tariffs paid by each organisation varied, responsibility for achieving best value passed to the club formula, where a narrative grounded in dominant theories about price competition guaranteed its attainment. Whether it *actually* achieved a better price than alternatives was not the core concern:

> Neither you nor anybody else … would be able to demonstrate that's produced better prices. However, there are plenty of diagrams and calculations to show how much money's been saved. But, let's say we save forty million, where's the forty million? Is that going back into the economy? It's all notional savings … So we're paying less now than we did last year … so why is that? Is that because it's a procurement exercise, or the market going down? And you're paying more, so is that because of procurement, or because the market's gone up? (Robert, estates manager, West City university B)

The value of the club formula was less a matter of price, or unequivocal financial savings, than of the protection this conferred on managers from exposure to media and public criticism. The practical inscrutability of the price formula meant that, rather than being adopted on the basis of an economic hypothesis (which human cognitive limitations would preclude testing), its efficiencies were treated as axiomatic. In contrast, collaborating in long-term contracts for heating and hot water supply from a local energy services company would expose the organisation, and its officials, to reputational risks; any perceived increase in energy spending could be blamed on the organisations, or even the managers personally.

The only heat market assemblage regarded as fair by all parties was an independent energy services company investing in a heat network, and taking responsibility for constructing a separate price offer to each party, which would then be judged on its merits. The West City parties however regarded the prospect of, as one put it, 'Joe Bloggs energy company' saying 'we'll invest in the whole scheme and supply whoever puts their hand up' as unlikely. Responding to the modelled cash flow and its embedded discount rate, they considered it more likely that each heat 'customer' would have to provide at least a proportion of the infrastructure finance in order to demonstrate the commitment necessary to attract external investors. This raised the prospect of protracted negotiations over shares of costs, benefits and responsibilities.

The 'right' heat users in the 'wrong' roles?

Securing the integrated energy, cost and carbon economies imagined by the heat market experiments relied on assembling long-term interdependencies between prospective buyers and supplier(s). Public procurement, budgeting and finance instruments however framed such interdependence as having *dis*economies, and constituted instead a motive for competition between public sector bodies. This did not eliminate reflexivity about the failure to address the collective actor problem of climate change, which was recognised as undermining a stated willingness to collaborate, and as likely to have some political consequences in the informal moral economy of public services. The resulting unease contributed to parties assessing *other* ways in which carbon saving objectives could be accommodated to the public services market actor network, and work to their advantage. Organisations proceeded to commission independent technical-economic models of CHP investment, with self supply of electricity as well as heat. The West City NHS team, for example, perceiving the modelled heat market to have limited benefits and disproportionate costs to them, commissioned a separate model which projected capital costs of one-third of the multi-party network, considerably higher financial return to the NHS, because of savings on electricity bills, and carbon savings of around 40%. These were however lower carbon savings than those *allocated* to the hospital in the multi-party model. In East City, procurement of the second hospital also proceeded with an NHS-only CHP system. One of the West City universities secured grant funding for a campus CHP system through a higher education sector initiative; the other West City university, building on understanding developed through engagement with heat market proposals, made a bid to the same funder. The East City university has also proceeded independently, and the enterprise agency had already built business facilities with stand alone gas boilers at the site.

These initiatives were not pursued deliberately to undermine the multi-party network, but as a means to increase the financial value captured by their organisation. The bounded, time-constrained and segmented rules of public sector finance also however conditioned an aversion to interdependence:

> Because [the grant funder] is giving the cash to ourselves it needs to be ring fenced around, [the funder] can't be giving us money to enable somebody else. … [In addition] Clock is ticking, usual government criteria is 'here's a lot of money and the key criteria is you need to spend it by a deadline'. (Michael, carbon and energy manager, West City university B)

The focus on financial advantage for each individual organisation creates an additional perverse incentive to run CHP engines even when heat production exceeds what can be used, hence undermining the logic of carbon saving:

> The bigger the CHP unit you put in, the more electricity you generate, which is where all of your financial savings come from, but then you have a hell of a lot of heat you need to get shot of … It's worthwhile for us to over-aim the size of the CHP slightly. There's a financial benefit to us, even if we just dumped all of the heat into the atmosphere. (Michael, carbon and energy manager, West City university B)

Although in some respects single user CHP provides a platform for subsequent area networks, the collective actor problem is more intractable, and the loss of any financial logic to support interconnection is stark:

> If the NHS have their system, […] and we have our system here, and there's four million pounds worth of interconnection work that needs to happen in between them, who is going to pay for that? (Michael, carbon and energy manager, West City university B)

Even if interconnection of the small networks could be financed, this would create a very different configuration from the modelled multi-party system, with reduced climate protection and welfare benefits. Large heat users represent significant long-term revenues for an energy services company, enabling repayment of capital. In both cities, however, the NHS hospitals and universities translated the modelled heat market into an opportunity to *sell* rather than buy heat, while gaining financially from self supply of electricity. A notional investor in an area heat network would be left dependent on a large number of smaller customers forming a market for surplus heat supplied by the large organisations. The heat network business investor would then have a large debt, low revenues, problems caused by concentration of demand in the coldest months of the year, and insecure returns. Ironically the technical-economic models set in train developments which undermined the collective actor solution of shared heat network infrastructure, making the envisaged carbon savings and societal benefits harder to achieve.

On not assembling a heat market

> I think there's a feeling that all the ducks are in the duck pond, but nothing's quite lined up. (Karen, East City council officer)

Neither heat market experiment, whether greenfield or retrofit site, nor any variant of original models, has thus far proved viable. The technical-economic model, relied on by government intermediaries as a market device to assemble a new actor, found no material purchase with either commercial investors, who were invisible in negotiations, or public sector parties. The latter contested the value to their organisation of such a venture, and resisted its interdependencies, making voluntaristic enrolment elusive:

> Even down at [science park site], you know, you just despair. If anything is set up to benefit from things like district heating in a properly coordinated support structure, your major new hospital sites with all this expansion for the next 20, 40, 50 years; you can't even have a sensible discussion about integration because it is all your different stakeholders, different contracts. Unless you're legislated it ain't going anywhere. (Andrew, East City university director of estates)

These public sector 'market players' were responsive to the modelled financial calculations, but assimilated them into far more potent public services market *agencements* constituted by the centrally governed rigours and material force of private finance and competitive procurement instruments, 'best value' public spending frameworks and segmented budget accounting rules. The resulting *organisation economicus* dis-embedded the public bodies and their officials from social ties of locality, mutual accountability and coordinated action, and legitimated competition between them. Those construed in the model as locally autonomous decision-makers emerge as only partially local. Although the officials representing each organisation continued to articulate a sense of moral responsibility to respond to climate change, this did not provide a foundation for common cause. Their discretion was constrained by the financial and contractual instruments configuring such market assemblages. The disciplining power of the instruments interacted with affective and cognitive dynamics, contributing to a conservative force towards continuation of current energy market transactions. Significant professional and personal hazards were implicated in the demands of commissioning and managing long term, complex private finance contracts. Heat network commissioning would be one more accretion in the web of contracting and outsourcing. Familiar cultural scripts, constituted around formal metrics, legitimated existing practices, sheltering officials and organisations from anticipated reputational damage. Since there was no necessity for them to value the common good, each party pursued the selfish rational actor solution, leaving the collective actor problem unresolved:

> The reality is we've no real need to operate at this level together … there's no need for us really to interact with the hospital. There's no real need for us to interact with the city council. There's no need for us to really interact with [university A] and even less with [West City Housing Association] … So somebody has to *bind* all those

> people together … First of all you have to force them to work together, and once you give them a common purpose, I think it will work, but it won't work naturally. (Robert, estates manager, west city university B)

Discussion and conclusion

Political-economic commitments to markets as means to solve societal problems pose important questions about the scope for their re-design to coordinate the urgent mitigation of climate change (Blunden & Arndt 2016). We have examined the 'careers' of two experiments to assemble markets for heat network infrastructure. These were led by government intermediaries as a means to solve the collective actor problem of building low carbon heat infrastructure as part of climate policy. Technical-economic models were intended to construct the market value to investors and heat buyers of a joint venture. The models however reduced the appraisal of value to a primarily financial measure. Public service professionals in universities, NHS and city councils understood the need for collaboration in principle, but in practice the primacy of finance metrics and cost competitiveness meant that they focused on contesting the calculations, and shares, of monetary costs and benefits. In this way, the model calculations were subsumed into the material market *agencements* of public services, constituting the interdependencies of a heat market as a cost to be avoided. The common purpose of climate protection was marginalised, and carbon saving reduced to what one party characterised as no more than a 'helpful bonus'. Government agencies themselves appeared to lack insight into the limits and contradictions of such market devices, suggesting the tensions and divergences of political purpose within governments over public services and private finance, energy markets and climate change.

The research findings also point to the need for further conceptual development of a material sociology of markets, notably in relation to the workings of power in such hybrid, and intersecting, market *agencements*, and the differential embedding of interests and values. Returning to a key conjecture of actor network theory, that forms of agency are defined by the particular socio-technical constituents of the network, it is evident that some network actors have little capacity for collaboration over public goods. More research is needed to understand the erosion of such capacities, evident here even in public services, and the societal consequences. In the UK, for example, it is primarily central governments, with control over statutory powers and budgets available to regional and city governments, which sets the frameworks of public accounting formulae, private finance and regulatory institutions. Sociology could contribute more to systematic analysis of such instruments, their formations of value, and their material effects in extending markets in public services.

The stalled assembly of low carbon heat markets in these cases, and unresolved controversies over the calculus of value, highlight the limits to plasticity in energy market experiments, and the need for constructive political and social challenge to such limits. Using markets to protect public goods of a stable climate is particularly difficult, given the highly established, powerful fossil fuel industry, and sunk investments in generation and supply technologies, on which we all rely. The industry is entangled in the political and economic process, and in the associated networks of regulatory incentives, taxes and business rates. Market experiments seem most feasible currently when little or no investment in new infrastructure networks is required. Improvised trading relationships are for example emerging around existing electricity grids, where decentralised and small scale electricity technologies and battery storage can be used to coordinate a virtual power plant, and hence contribute to balancing electricity supply and demand. Such experiments are unlikely when new capital-intensive network infrastructure *is* needed, and there are incumbent, affordable alternatives, as in the example of heat vs. gas grids. The idea of the heat grid in clean energy policy is premised on its future adaptability for experiments in heat recovery from sources currently wasted, but current markets lack any actor willing to take responsibility for investing in such long-term public goods.

Making such an actor requires re-engagement across business, state and civil society in deliberative governance processes of the kind envisaged by Callon (2009) in his account of civilising markets. If policy aspirations for low carbon heat from new network infrastructure are to be realised, governments and publics need to address the disabling effects of segmented public sector cost metrics, and the economic and human costs of long term, inflexible concession contracts with private investment consortia. The risks of economic short-termism, the reliance on price as a proxy for value, and failure to encompass the societal value of innovation for clean energy need to be at the core, not the margins, of negotiations about the substance and structuring of markets. This means enquiring into the configuration of economic agencies with capacities beyond those of maximising financial return. A starting point for assembling local heat markets for example is likely to be political and senior management sponsorship of long-term investment in decentralised energy infrastructure at social discount rates. The first steps of this kind are being taken by the UK government through a £320 million capital fund for heat network investment, and open consultation about fund management principles (UK Government DECC 2016). Greater devolution of financial and budgetary powers to city and regional governments would also lay groundwork for cooperation in identifying common purpose at locality scale. Conditions under which at least *some* parties find collaboration for a low carbon energy system to be crucial to their objectives may then be assembled. Such governance issues are more than academic: there is pervasive concern, manifest in our research, about who will take responsibility for what actions to develop a clean, affordable and secure energy system, accountable to the public.

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Notes

1. 'By 2050, all buildings will need to have an emissions footprint close to zero' (UK Carbon Plan 2011, p. 5). Forty-five per cent of current emissions from buildings are associated with use of fossil fuels for heating.
2. Gas CHP remains a common platform for establishing heat networks in the UK, and provides higher technical efficiencies in fuel conversion, by using the waste heat from generation of electricity. The potential for subsequent connection of locally available heat sources, such as biomass, biogas or energy from waste facilities, is treated as a means to secure further carbon savings.
3. The researchers co-organised five workshops (web site reference to be inserted).
4. A non-profit company originally set up by UK Government to manage carbon reduction programmes.
5. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/418505/Revised_Best_Value_Statutory_Guidance_final.pdf
6. https://www.gov.uk/guidance/crc-energy-efficiency-scheme-qualification-and-registration#overview

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